OBSERVATIONS ON HEARING AND SMELL IN SPIDERS.[1]

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ONLY a small amount of previous work has been done upon the senses of hearing and smell in spiders.

According to Campbell ('80) spiders are well provided with the means of feeling the slightest movements of their webs or other near objects. On their legs are long, slender, silken hairs which differ from other hairs in that they are attached to a disc on the integument.

Dahl ('83) found these hairs to vibrate to the tones of a violin and designated them as auditory hairs. Later ('84) he distinguished certain of these as organs of smell and attempted a classification of spiders according to the distribution of the various hairs.

Bertkau ('85) compared the so-called taste organs on the ends of the palps with the flask-shaped bodies on the antennæ of ants and spoke of them as organs of smell.

J. W. and E. S. Peckham ('87) found that with three exceptions all the spiders experimented upon by them gave responses to strong smelling substances, but the Epeiridæ alone seemed capable of hearing the vibrations of a tuning fork. Orb-making spiders were the most sensitive to these vibrations, while those that make no web gave not the slightest heed to the sounds, and in the former the sense seemed to be distributed generally over the whole epidermis.

Wagner ('88) insisted that the so-called auditory hairs are only capable of perceiving tactile sensations.

Gaubert ('90) considered the lyriform organs as organs of hearing.

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McCook ('90) concludes that the senses of smell and hearing are very rudimentary and are distributed over the entire body. They are located in the delicate hairs which constitute the covering and armature, so that the nervous system receives through these organs or appendages impressions that may be considered analogous to hearing and smell in the higher animals. Further, the sense of hearing can scarcely be distinguished from that of touch as it is known to us. He thinks that even in the orb-weavers there is no true sense of hearing, but that the web filaments transmit the vibrations and the sensation is tactile rather than auditory.

Pocock ('93) found spiders sensitive to heat, provided with acute sense of taste, with defective sight and no hearing whatever.

Dahl (:04) designates the auditory hairs as trichobothria and makes an elaborate classification of suborders according to their distribution.

The two species used by me for experiment are *Geolycosa texana* Montg. and *Pardosa mercurialis* Montg. and are found in great abundance in Austin, Texas, and its vicinity. The large *Geolycosa texana* lives in underground holes of $\frac{1}{2}$ to $1\frac{1}{2}$ inches in diameter and digs its home on creek banks or in the fields wherever the ground is comparatively clear except for a close sod of native grass. *Pardosa mercurialis* has been found mainly under small surface stones along the banks of streams or in the dry beds during droughts, but sometimes occurs in great abundance far from water.

The specimens used for the observations were kept in cages made by fastening glass plates together at their edges with gummed linen, as described by Montgomery (:03).

1. EXPERIMENTS ON HEARING.

The apparatus used for these experiments were tuning forks of 128, 256, 320, 384 and 512 vibrations and a specially prepared, isolated cage. The cage was made of three glass plates fastened with gummed linen and covered with black paper,

except on the bottom. A small hole was left in the paper of one side to admit light and one in the top for observations. The bottom was of mosquito netting which served to admit the sound waves from below. The cage, supported at the three corners by wooden posts 10 *cm.* high, rested on a wooden float, the float in a stone jar filled with water and attached to it by rubber bands. A layer of sawdust three inches thick isolated the jar and stool upon which it stood from vibrations from without. The apparatus, though placed in a quiet, darkened corner of the laboratory, was used only when there were as few outside disturbances as possible.

a. Geolycosa texana Montg.

♀ No. 13 was placed in the hearing cage and left unmolested one hour. At the end of that time successive trials were made with tuning forks of 128, 256, 320 and 512 vibrations, but no response whatever was obtained. At two later dates the experiments were repeated but with no more definite results. The same results were obtained with three other females, in each case using all the tuning forks. Also a male, after remaining quiet one hour in the hearing cage was tested with all the forks but gave no response.

b. Pardosa mercurialis Montg.

♀ No. 5 was placed in the hearing cage and after an hour's intermission was tested with the forks but remained perfectly quiet. She was left in the cage over night and tested next morning but gave no response.

♀ No. 6 was tested by three separate series of experiments, the first after two intervals of an hour and the third after a half hour had elapsed, but she did not respond to any of the sounds. During the first series she cleaned her palps and legs in the normal way as if nothing unusual were happening. No responses were obtained on similar experiments with two other females and a male.

At another time a steel bar which gave a pitch of approxi-

mately 2300 vibrations was suspended above the hearing cage and struck repeatedly with a metal hammer. Eight fresh specimens were placed successively in the cage but no spider made any motion that could be interpreted as a response to the sound.

Again, a mason's trowel was held near the cage and struck several times with a metal bar producing a loud, crashing noise, but the spiders made no motion whatever.

2. Experiments on Smell.

These experiments were undertaken to ascertain first whether the spiders possessed the sense of smell and second to localize the same, if possible, in case it was found to exist. The experiments were made mostly upon *Pardosa mercurialis*.

Two classes of the essential oils were used as tests. Those of the first class were the non-irritants, lavender, cedar, wintergreen, almond, juniper-berries, bergamot, cassia and cloves; of the second class, those irritants that will cause sneezing in man were oils of mustard and black pepper. The results from the use of the two irritating oils were essentially the same as those for the stronger oils of the non-irritating class, and the reactions were the same in every case only that they were more intensified with the oils of stronger odors.

The hearing cage was used for the smell experiments.

Small glass rods were dipped into the oil and the drop that adhered was held immediately below the cage. In each case the spider seemed repelled to a greater or less degree corresponding to the strength of the oil, and in no instance was it attracted toward the stimulus. The males and females gave exactly the same response, thus showing that neither sex has a superior sense of smell.

The responses were (1) turning away and moving as far as possible from the odor, (2) vibratory movements of the palps and mandibles, (3) raising each leg as the oil is applied beneath it. In some cases all the responses were given to a single stimulus, in others only one, or a combination of either two.

Experiments were made first on unmutilated specimens to

ascertain the normal reaction to odors, then upon individuals variously mutilated in order to localize the olfactory sense.

a. Observations on Unmutilated Individuals.

Lavender.— Tests were made with eight females and seven males and each responded by running from the stimulus. In four cases this was accompanied by motions of the palps and mandibles.

Wintergreen. — Seven females and four males. In five cases the palps gave definite vibratory responses and in the others the spiders turned away.

Bergamot. — Six males and six females. Each time the spiders turned away, and in seven instances responded with motions of the palps.

Cassia. — Six males and six females. All but one turned quickly away, and eight gave vibratory motions of the palps.

Clove. — Six females and five males. One female gave no response, six gave movements of palps and mandibles, while ten responded also by turning away.

Cedar. — Eight females and six males. The responses were quite indefinite, palpal vibration in two cases, and in four there was no motion whatever.

Almond. — Seven females. No palpal movements were given and the spiders turned away indifferently.

Juniper-berries. — Eight females and six males. The responses were quite slow and consisted generally in turning away. The palps were moved slightly but not in a vibratory manner.

Mustard. — Six males and eight females. The responses were no more decided than those given to strong oils of the non-irritating class. In only one instance were there definite palpal movements, and the spiders usually turned quickly away at first, then later more slowly, as if overcome by the odor.

Black pepper. — Six males and six females. The responses were quite slow and given after prolonged stimulation. Vibratory motions of the palps were entirely lacking.

b. Observations on Individuals with Palps extracted.

It next seemed desirable to determine the location of the olfactory sense, and for this purpose the oils that produce definite results with the unmutilated individuals were used exclusively.

Both palps were extracted with forceps at the femoro-trochanteral joint from twelve females and six males, and after a week had elapsed experiments were made with three non-irritating oils, lavender, wintergreen and bergamot.

Lavender.— In every case the spider gave definite responses to the stimulus. When the drop of oil was held directly beneath each leg successively, each responded by a slight, quick, upward jerk. Almost without exception the first pair were raised highest and held poised in the air several moments or until the other legs were stimulated. The second pair were not raised so high as the first, nor the third pair so high as the second, and rarely ever both at the same time. The fourth pair were usually raised only a little distance and then drawn up closer to the body while the spider moved away.

Wintergreen. — The same specimens, twelve females and six males, were used and practically the same results were obtained.

Bergamot.— A similar series of experiments was performed on the twelve females and responses corresponding to the above were given, though bergamot appears to offer a weaker stimulus than the other two oils used.

Cassia.— The palps were extracted from twelve other males and six other females and experiments were performed after twenty-four hours. In only one instance did the spider fail to respond, all others showing the usual reactions — the first pair of legs responding most definitely and the others less so. The spiders usually turned away after a few applications of the stimulus.

c. Observations with the First Pair of Legs Removed.

In five females and six males the palps were left intact but the first pair of legs were similarly removed with forceps. The

responses were exactly the same as in the foregoing series. Thus it was shown that the sense of smell is not localized in the palps nor in any one pair of legs, but that each is capable of perceiving the stimulus to a certain degree and of giving a definite response to it.

d. Observations on Individuals with the Sense Hairs removed.

The theory has several times been advanced that the long, spiny hairs on the legs of these spiders are organs of special senses, accordingly all these hairs were cut off the tarsi and tibia of male No. 94 and after twenty-one hours it was tested with lavender oil. Each leg responded as do those from which no spines were removed.

Female No. 95 had the hairs cut from the entire leg and each leg sand-papered, still it gave the normal response to bergamot twenty-one hours after the operation.

Female No. 96 had all the legs sandpapered, yet after only an hour's time it responded normally to bergamot, raising each leg in succession.

Male No. 97 had the tarsus of each leg removed and the spider seemed to suffer more than when an entire leg was cut off. However after twenty-two hours it responded normally to bergamot, raising each leg as it was stimulated. It was not considered safe to cut the legs at any higher joint, but the experiments seem to indicate that the entire leg possesses the ability to perceive sensations of odors.

3. Conclusions.

1. Neither Geolycosa nor Pardosa respond to tuning forks of 128, 256, 320, 384 and 512 vibrations. No responses were given to a metal bar of approximately 2300 vibrations nor to the crashing sound of a metal plate when struck with a bar. Therefore it is quite probable that these spiders do not hear at all.

2. It might be supposed that possibly this extreme quiescence was itself an indication that the spiders perceived the tones and responded in this way; however the fact that these spiders

remain motionless in their cages for hours together seems to prove that the sound is not perceived in any measure, or at least that it produces no response. All parts of the body are extremely sensitive to touch and the spider responds immediately if it or the cage comes in contact with the vibrating tuning fork.

3. Males and females respond exactly alike to stimuli of smell and hearing.

4. Pardosa responds normally to the essential oils by turning away, making vibratory movements with palpa and mandibles, and raising each leg as it is stimulated.

5. Individuals from which the palps have been removed respond to odors normally with each leg.

6. Individuals with the first pair of legs removed respond normally with the palps and the remaining three pairs of legs.

7. Spiders that have had the sense hairs cut off or sand-papered respond as do normal specimens.

8. Specimens with the tarsal joint cut from each leg respond as usual by raising each leg when stimulated.

9. From the foregoing results it seems quite evident that the ability to perceive odors is distributed over the whole integument of the spider and there is no definitely localized olfactory organ.

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